Specific models to assess the possible use of alternative external carbon sources for nitrogen removal in wastewater treatment.

By

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CERTIFICATE OF ORIGINAL AUTHORSHIP

This is to certify that I am responsible for the work in this thesis, and to the best of my knowledge it has not been submitted for a degree or for part of a degree requirement to another institution, unless fully acknowledged in the texts.

I also want to certify that I have written this thesis, with helps and supports as mentioned in the acknowledgements, and to the best of my knowledge, all information sources and literature used are indicated in the thesis accordingly.

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Abbreviations

Symbol	Description
bCOD	Biodegradable COD
BOD	Biological Oxygen Demand
C:N	Carbon: Nitrogen Ratio
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
F/M	Food/ Microorganism Ratio
GAOs	Glycogen-Accumulating Organisms
HRT	Hydraulic Retention Time
IR	Internal Recycle/ Internal Return
MLE	Modified Luzack-Ettinger
MLSS	Mixed Liquor Suspended Solids
MLVSS	Mixed Liquor Volatile Suspended Solids
NMB	Nitrogen Mass Balance
OUR	Oxygen Uptake Rate
PAOs	Phosphate-Accumulating Organisms
PHA	Polyhydroxyalkanoate
PHB	Polyhydroxybutyrate
rbCOD	Readily Biodegradable Chemical Oxygen Demand
sbCOD	Slowly Biodegradable Chemical Oxygen Demand
SBRs	Sequence Batch Reactors
SDNR	Specific Denitrification Rate
SDNR (t°C)	Specific Denitrification Rate at T^{o}c
SE	Significant Error
SOUR	Soluble Oxygen Uptake Rate
SRT	Sludge Retention Time
SS	Suspended Solids
SVI	Sludge Volume Index

TKN	Total Kjeldahl Nitrogen
TN	Total Nitrogen
TOC	Total Organic Carbon
TSS	Total Suspended Solids
VA	Volatile Acid
VFA	Volatile Fatty Acid
VSS	Volatile Suspended Solids
WAS	Wasted Activated Sludge
WWTP	Wastewater Treatment Plant

PhD Dissertation Abstract

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Abstract

Achieving effective denitrification in municipal wastewater treatment is amongst one of the world's biggest environmental challenges to sustainability. The problem is specifically due to the slow denitrification rate in the anoxic zone, which is caused by the lack of readily biodegradable organic carbon. Without effective treatment, the excessive discharge of nitrogen into waterways can cause eutrophication, deterioration of water sources and danger to human health. Various solutions including the construction, expansion and modification of existing wastewater treatment plants (WWTPs) to meet the increasing demand, however, often require the whole treatment plant being redesigned, with high investment cost, more operating expenses, and retraining of existing staffs.

An alternative strategy is adding an external carbon source directly into the anoxic zone. The advantage of this option is: (i) it is easy to implement, (ii) it requires little modification to an existing WWTP (so high costs and treatment plant operations will not be overly affected), and (iii) it can meet both the short-term and long-term treatment standards. The search for a material that is readily

degradable, inexpensive, and preferably to be either a waste material or by-product with favourable C:N ratio from local industries, has been ongoing in the last few decades, and is also the central theme of this research.

The original contribution this research makes to our knowledge of the topic is done by simulating the potential of industrial-grade sucrose and fermented biosolids. These are two less well-studied carbon subgroups that can act as external carbon sources for improving denitrification in municipal wastewater treatment. This task was specifically achieved by establishing a systematic cross-verification of various mathematical, conceptual and physical models, which will not only provide more information about the two carbon sub-groups, but also help to identify various flaws and disadvantages each model may carry. Despite both sucrose and various other fermented sludge types being experimented upon in this thesis, the real original research subjects of this study are the fermented and dark fermented biosolids, two substances within fermented sludge subgroup. They were selected based on the results of a series of fermentation batch tests.

Meanwhile the reason why industrial-grade sucrose was also studied despite it not being necessarily new is, firstly, due to sucrose's insignificant nitrogen content, consistency and uniform characteristics; this makes it the perfect subject to test and develop the cross-verification methodology. Secondly and in reference to future research on this topic, sucrose is the product of cellulose hydrolysis, which has very similar optimal operation conditions (in terms of pH and temperature) with sludge fermentation. This indicates the future potential for utilising cellulose hydrolysis in the same sludge fermenter to improve and optimise fermented sludge generation.

The results indicated that while sucrose could be used to improve the denitrification process and treat several treatment scenarios down to below standard, fermented and dark fermented biosolids however, provide a much better treatment performance, and complete denitrification in almost all simulations. In fact, its maximum potential is exceptional that within the scope of this study, it was only limited by the treatment demand rather anything else.

The results also found that the NMB models and cross-verification methodology being established by the candidate were very successful in simulating the effects of adding sucrose and fermented biosolids on denitrification improvement. It is however recommended to apply these models and methodology into future external carbon source study, not only to detect their flaws and drawbacks, but also to improve them accordingly.

Keywords: Sucrose, fermented sludge, external carbon source, modelling cross-verification, cellulose hydrolysis.